AN EXPLORATORY STUDY OF ON-SITE BALANCE RECOVERY TRAINING FOR RESIDENTS OF RETIREMENT COMMUNITIES

A Thesis

by

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ABSTRACT

Approximately half of all falls among adults age 65 and older result from tripping. Therefore, improving the ability to recover balance after tripping may be an effective approach for reducing the number of falls among these individuals. Balance recovery training (BRT) is a novel exercise intervention that has the potential to improve balance recovery ability after a trip. The goal of this study was to evaluate the efficacy and feasibility of BRT as an on-site intervention for improving reactive balance recovery ability among residents of retirement communities. BRT involved twelve 30-minute sessions over four weeks. During each session, subjects were safely and repeatedly exposed to postural perturbations that mimicked a trip using a modified treadmill. The active control, Tai Chi, involved the same number and duration of sessions as BRT. A battery of balance and mobility tests were performed before training and one week, one month, three months, and six months after training to assess changes in response to training, and differences between groups.

The efficacy of BRT was supported by greater improvements and retention in many balance recovery measures compared to subjects who completed Tai Chi. The feasibility of BRT as an on-site intervention was also assessed using semi-structured interviews of subjects to determine overall perceptions of BRT as well as suggestions for sustainability of BRT. BRT subjects rated the intervention positively and provided useful feedback for implementation of a more permanent BRT program.

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The data analysis for Project 1 was conducted in part by Leigh Allin of the Department of Biomedical Engineering.

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NOMENCLATURE

BRT	Balance Recovery Training
TC	Tai Chi

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INTRODUCTION

Falls are a leading cause of injuries and injury-related deaths among older adults in the United States [1]. Approximately half of all falls among older adults occur due to tripping [2-4]. Therefore, an improved ability to recover balance after tripping may be an effective approach for reducing falls among older adults. Task-specific balance recovery training (BRT) is a novel fall prevention intervention that aims to improve this ability by leveraging the motor learning principle of specificity of training. It focuses on training the specific sensory and neuromuscular performance requisites involved in balance recovery after tripping. BRT involves repeatedly exposing individuals to trip-like postural perturbations in a safe, controlled environment to facilitate improvements in reactive balance recovery. On the other hand, Tai Chi (TC) was chosen as the control intervention based on two ideas: (1) TC has a positive effect on balance and fall rate; (2) TC strongly contrasts the conceptual approach of BRT as it focuses on training balance by practicing slow, volitional movements in various postures. The goals of this study were to evaluate the efficacy (Project 1) and feasibility (Project 2) of BRT as an on-site fall prevention intervention for older adults.

Project 1: Evaluate the efficacy of BRT versus TC on balance recovery and clinical measures of balance and mobility among older adult residents of retirement communities

To evaluate the efficacy of BRT, residents of retirement communities were assigned to either BRT or TC training conducted on-site. Five assessment sessions consisting of trip-like postural perturbations and clinical measures of balance and mobility were also performed. These assessments took place at baseline (prior to training), and one week, one month, three months, and six months after completing training.

Hypothesis 1: Compared to TC subjects, BRT subjects will show greater improvement and retention in balance recovery ability compared to their baseline measures.

Hypothesis 2: Compared to TC subjects, BRT subjects will show lesser improvement and retention in clinical measures of balance and mobility compared to their baseline measures.

Project 2: Assess the feasibility of providing BRT in retirement communities, including issues related to older adult subject recruitment and compliance

To evaluate the feasibility of BRT as an on-site fall prevention intervention for older adults, qualitative data on subjects' perception improvements of the BRT will be collected.

Hypothesis 3: Subjects at retirement communities will rate BRT positively, and provide important feedback on how BRT would best be implemented and sustained in these settings.

BACKGROUND

One approach to improve balance recover ability has included exercise interventions focused on improving lower limb strength, but has unsuccessfully transferred to influence limb responses after a laboratory trip [5]. One proposed reasoning is because strength exercises do not practice motor skills specific to recovering from a trip. During motor learning, the nervous system changes structurally and functionally, specific to the demanded task, and requires practicing tasks that are complex enough to increase cognitive processing [5].

Motor Learning

Motor learning is a relatively permanent change in either the behavior or performance of a subject as a result of practice and/or experience. Motor learning consists of three processes: learning, retention, and transfer. During the learning process of a movement, the subject must receive either implicit or explicit feedback that directs a change in performance. Through repeated practice and feedback, performance can be improved. The learning phase is complete once the task becomes largely autonomous. Retention, the second process of motor learning, is the extent to which the desired task can be maintained after the practice session(s) are complete. Retention measures the degree to which the practiced task has become a habit, independent of practice. Finally, transfer is associated with the extent to which practicing a particular task influences the performance of a new task. The successful transfer of one task to another primarily depends on the repetition and specificity of the practiced task. In fact, the training principle of specificity of training indicates that the transfer of a practiced task to a targeted task can be improved by making the practiced task as similar as possible to the targeted task.

Motor learning has been applied in a balance training context by mimicking fall-like scenarios during the training. These approaches include inducing a perturbation using waist pulls [5], moving platforms [7-10], and treadmills [5, 11-13] in order to cause a large enough disturbance to induce a stepping response to avoid a fall. Such approaches that focus on motor learning have been used to improve standing balance [8, 9], balance after an induced slip [10, 14, 15], and balance after an induced trip [5, 11-13, 16, 17] with the hopes of reducing the rate of falls in older adults.

Training Standing Balance

Common contributors to a fall include the inability to produce sufficient postural responses such as rapid stepping or grasping movements to recover balance. Compared to young adults, older adults exhibit less postural control after being exposed to an external perturbation, such as a slip or trip, often leading to several compensatory steps to regain balance [8]. One approach to improving an individual’s postural control is to improve their standing balance. Standing balance is defined as the ability to maintain balance without stepping after exposed to a small external force or perturbation [9]. To improve standing balance, perturbation training is commonly used, which consists of repeatedly exposing an individual to perturbations. These perturbations, caused by either applying a force to the body or displacement perturbation to the standing surface, allows the individual to repeatedly practice the motor skills specific to maintaining balance. One particular study, assessing the effect of perturbation training on standing balance in older adults found that subjects improved their postural control by decreasing their center of mass (COM) displacements both anteriorly and posteriorly and retained the improvements 24 hours later [8]. Interestingly, the same study demonstrated that the older adults with the largest COM displacements at baseline improved the most and took significantly fewer steps post intervention. Therefore, a ceiling effect might be present where the more balanced individuals might not benefit from perturbation interventions as much as others [8]. Platform perturbations have also demonstrated a reduction in frequency of foot collisions, multi-step reactions, and an increase in anterior/posterior step displacement in older adults after a 6-week intervention [9]. Although promising changes in postural and stepping control have been observed in studies focused on training standing balance, other researchers have investigated the direct application of perturbation training to improve stepping responses after an induced slip and trip.

Training Balance after Slipping

Slipping is one of the largest causes of injurious falls among older adults. A slip is initiated when at least one foot makes contact with a low friction surface, displacing a person's base of support. Successful recovery from a slip has often been associated with an ability to quickly adjust one's base of support or grasp onto a nearby structure [18]. Perturbation training has been largely implemented to reduce falls after a laboratory induced slip. In a particular study, Pai et al 2010 [10] demonstrated that older adults, compared to young adults, were twice as likely to fall on the first, unannounced induced slip administered both while walking as well as during a sit-to-stand activity. Nevertheless, after an intervention composed of five repeated slips while walking and during sit-to-stand, older adults were able to decrease their incidence of falls to less than 5% by the 5th slip in both tasks. Pai et al. 2014 [15] also investigated the effect of a training session of 24 repeated slips on recorded falls up to 1 year after training. They found that subjects who participated in the repeated slip training reduced their rate of falls to 0% by the 24th slip and reduced their falls outside the lab by 50% over the next 12 months [15]. Positive results associated with repeated slip training shows promise as a method in which to reduce slip-induced falls outside of the laboratory.

Training Balance after Tripping

Tripping is also one of the largest causes of injurious falls among older adults. A trip is initiated when an uneven surface or obstacle obstructs a person's swinging foot while walking [4]. Successful recovery from a trip has often been associated with a fast reaction time, control of the forward rotation of the trunk, and a sufficiently long recovery step length in order to provide a sufficient base of support [16]. Interested in investigating the benefits of perturbation training to improve recovery after a fall, Owings et al. [12] investigated adaptions of stepping responses after exposure to repeated simulated trips on a treadmill. In the study, community dwelling adults (65 years or older) were exposed to five 0.89 m/s (2.0mph) perturbations. Subjects who failed to recover on their first, "untrained" perturbation, demonstrated slower reaction time, shorter step lengths, and greater trunk flexion angles and velocities at time of recovery foot ground contact. Interestingly, 18 out of the 23 subjects who initially failed to recover on their "untrained" response, recovered on the four other perturbations, demonstrating a learning ability. Furthermore, those 18 subjects had longer recovery step lengths (on average 9% body height longer), as well as decreases in trunk angle and velocity on their four remaining perturbations. Previous work in the lab [11] has also demonstrated positive results with perturbation training. Compared to the control, where subjects walked for 15 minutes, subjects who were exposed to 20 induced trips demonstrated decreased maximum trunk angle and time to maximum trunk angle as well as increased hip height. Furthermore, Grabiner et al. [5] found that in other studies focused on treadmill induced trips, fall rate was reduced by 20% 6 months after a 6 month training [19], 80% in older women after a multiple week training, and 50% 12 months after a 2 week treadmill training session [5]. With retention rates demonstrated even after a 2-week intervention, repeated trip training shows promise as a method in which to reduce trip-induced falls outside of the laboratory.

Using a Treadmill to Train Balance after Tripping

While there have been several mechanisms to administer a postural perturbation, including waist pulls [5] and moving platforms [7], Owings et al. [12] were specifically interested in determining the similarities between failed recovery mechanisms of older adults after a trip induced by a treadmill compared to an actual trip. A modified treadmill, capable of quickly accelerating, can rapidly displace a person's feet posteriorly, placing their body in a forward falling position similar to one during an actual trip. With treadmill-induced trips, subjects can incorporate motor learning by practicing skills specific to recovering from a trip, in a safe, controlled environment. [11]. Initially, failed recoveries on the treadmill involved slower reaction times, shorter step lengths, and larger trunk flexion angles and velocities, as in an actual trip. Furthermore, many subjects who initially failed to recover increased their reaction time and step length as well as decreased their trunk angle and velocity at toe off and ground contact. Overall, Owings et al. [12] found that the mechanisms required to recover from a treadmill induced perturbation were found to be similar to general biomechanical recovery strategies. The findings of this study demonstrate the utility of using a modified treadmill to induce a trip-like perturbation, and improve balance recover ability.

A key component of recovering from a trip is fast reaction time [16], a skill repeatedly practiced in perturbation training. With the use of a modified treadmill to induce a trip, reaction time can be varied by adjusting the speed of the perturbations. One study found that reaction time (compared to walking velocity) had a greater effect on trunk angle [17], which has been shown to be one of the largest discriminating variables between subjects who successfully recovered after a trip and those who did not [12]. Additionally, inducing a trip with the use of a modified treadmill allows for the use of a block to represent a real-life tripping obstacle. In order to assess the influence of an obstacle on stepping response during an induced trip, one study investigated the differences between a trip induced by a treadmill (without an obstacle) and an induced trip while walking caused by an obstacle that would intermittently pop up. The study found that maximum step height, vertical peak velocity of the leading and trailing limbs, reaction time, and leading leg step length were significantly larger after a trip with an obstacle as opposed to one without [13], justifying the use of a block for the proposed study.

Novel Components of Study

Balance recovery training (BRT) is a novel exercise intervention that focuses specifically on improving balance recovery ability in an effort to reduce the number of falls among older adults. BRT involves repeatedly exposing individuals to postural perturbations in a safe, controlled environment to facilitate improvements in reactive balance recovery. My proposed work, building off previous work demonstrating positive results after perturbation training, included two specific, novel, aspects. First, I incorporated Tai Chi as my active control in order to better assess the effect of (BRT) as a balance recovery intervention. Previous studies involving perturbation training have results based off experimental controls such as walking [10, 11] and stretching exercises [5, 9]. Tai Chi, a more traditional approach to improve balance, has demonstrated positive effects on clinical balance/mobility measurements such as functional reach, get up and go test, and speed walking [20], therefore making it a more ambitious control for comparison. Second, both BRT and TC components of my proposed study were conducted on-site at the local retirement communities. The previously mentioned studies focused on balance recovery interventions have all been conducted in a laboratory setting. By providing a balance recovery training program where subjects reside, I was able to assess the feasibility of BRT as a training program that could be implemented and sustained at local retirement communities.

METHODS

Subjects

Thirty older adult residents (63 – 93 years old, 18 females) of local retirement communities participated in the study. Subjects were excluded if they (1) were less than 60 years old; (2) could not walk without the aid of an assistive device; (3) had a bone mineral density of the proximal hip with a score less than $t = -2.0$ based upon a Dual Energy X-ray Absorptiometry (DXA) scan (Hologic Inc., Hologic Discovery W QDR series, Waltham, MA); (4) received a score less than 24 on the standardized mini-mental state exam (MMSE [21]); or (5) previously participated in Tai Chi classes. Subjects were recruited through initial information sessions presented at each of the three retirement communities, flyers, and through word of mouth. This study was approved by the Institutional Review Board at Texas A&M, and written consent was obtained from all subjects prior to participation.

Subjects were assigned to either the BRT (n = 18) or TC (n =12) group using minimization allocation [22], which was based off of age, gender, and a subjective rating of balance recovery ability determined from the baseline assessment. A description of subject recruitment and group allocation is depicted in the Consolidated Standards of Reporting Trials (CONSORT) flow diagram (Fig. 1).

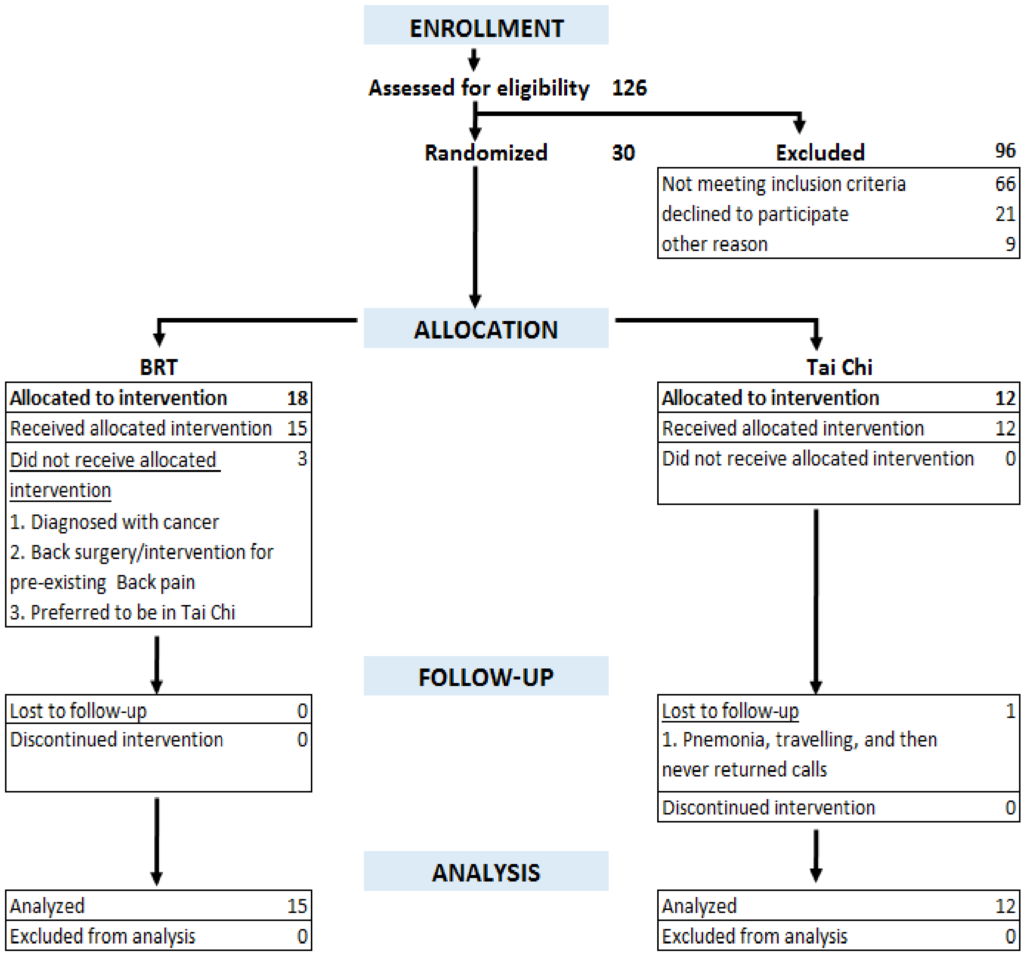


Figure 1. CONSORT flow diagram depicting total number of interested subjects, allocation of eligible subjects, number of subjects who completed the program, and number of subjects used in analysis.

Experimental Design Overview

Subjects who met all inclusion criterion underwent a baseline assessment where clinical measures of balance and mobility as well as balance recovery on a modified treadmill were recorded. Then, subjects were assigned to either the BRT or TC group and performed their respective training sessions three times a week for four weeks (12 sessions total). Both groups were then performed assessments one week (1W), one month (1M), three months (3M), and six months (6M) after the end of training (Fig. 2).

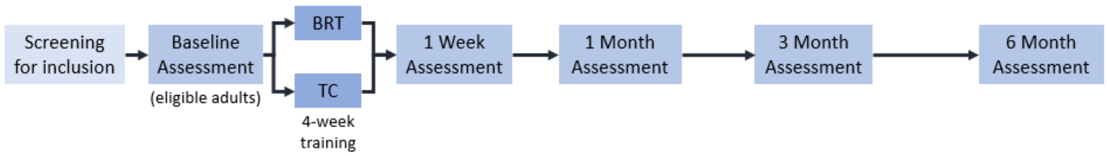


Figure 2. Schematic of the experimental design consisting of two groups (BRT and TC). Eligible adults participated in a baseline assessment (pretest) and four assessments (posttests) one week, one month, three months, and six months after their randomly assigned four-week training intervention group.

Project 1: Evaluate the efficacy of BRT versus TC on balance recovery and clinical measures of balance and mobility among older adult residents of retirement communities

Before subjects were allocated to either BRT or TC, baseline measurements were recorded and used for comparison with subsequent assessments. Baselines measurements consisted of clinical measures of balance and mobility as per standard protocols (listed below), subjective rating of balance recovery ability, and balance recovery measures on the modified treadmill. These assessments were intended to provide a broad evaluation of the effects of BRT and TC on standing balance, overall mobility, and balance recovery and include:

1. *Timed Up & Go Test* [23] as a simple measure of mobility;
2. *Berg Balance Test* [24] to measure functional balance;
3. *Unipedal stance time* [25] as a measure of sensitivity to balance training and fall risk;
4. *Performance-oriented mobility assessment (POMA)* [26] as a measure of mobility in older adults;

5. *Activities-Specific Balance Confidence Scale* [27], as a measure of fear of falling;
6. *Maximum forward step length test* [28] as a predictor of fall-risk relevant mobility and a key outcome in the [29];
7. *Subjective rating of balance recovery ability* on the modified treadmill assessed by a group-blinded member of the lab using a three point ranking system. A summary of the ranking system is provided below while the extensive rating rubric can be found in Appendix A1.
   7.1. Score a '1' if any of the following are met (total score is approximately < 12):
      7.1.1. Subject has difficulty recovering and stepping over block at 0.8mph (on one or both attempts)
      7.1.2. Subject falls at 1.6mph or is unable to step over block (both attempts).
      7.1.3. Subject does not attempt fast perturbations
   7.2. Score a '2' if any of the following are met (total score is approximately 12-24):
      7.2.1. Subject is able to recover and step over block at 0.8mph (one or both attempts), but has some difficulty recovering balance or stepping over block at 1.6mph (on or both attempts)
      7.2.2. Subject unambiguously falls and makes no attempt to recover balance and/or is unable to step over block at 2.4mph (one or both attempts)
      7.2.3. Subject recovers their balance at all speeds, but while holding a spotters' hands
   7.3. Score a '3' if any of the following are met (total score is approximately 25-30):

7.3.1. Subject is able to recover balance and step over block at all 0.8 and 1.6mph attempts. Subject recovers or nearly recovers balance at 2.4mph (both attempts)

7.3.2. Subject successfully steps over block at all speeds

8. *Balance recovery measures* on the modified treadmill were measured by stepping parameters based off previous studies [11, 12] using sagittal plane video recordings. Stepping parameters were calculated for the subject's initial step over the obstacle. Those stepping parameters include:

8.1. Step length, measured from toe of stance leg to toe of stepping leg at point of first touchdown.

8.2. Step time, measured from time of stepping leg liftoff to stepping leg touchdown.

8.3. Anterior/Posterior (A/P) stepping speed, measured by dividing step length by step time.

8.4. Reaction time, measured from onset of treadmill movement to time of stepping leg at liftoff.

8.5. Subjective rating of harness support, ranked on a three-point scale defined by no harness support visible for recovery (0), moderate harness support for recovery (1), and heavy reliance on harness for recovery (2)

In order to calculate the stepping parameters mentioned above, the original sagittal plane video recording was first processed in MATLAB. Virtual lines every 0.035m were overlaid on top of the modified treadmill as well as a time stamp of the video recording, which was based off the 100Hz sampling rate of the camera (Fig. 3). Two research assistants who were blinded to group allocation, independently calculated the aforementioned stepping parameters. The virtual lines were used to calculate step length while the time stamp was used to calculate step time and reaction time. Anterior/posterior speed was derived from these two calculations while harness support was a subjective rating based on the subject’s reliance on the harness for recovery. The independently calculated stepping parameters were then compared and averaged in an attempt to mitigate human error.

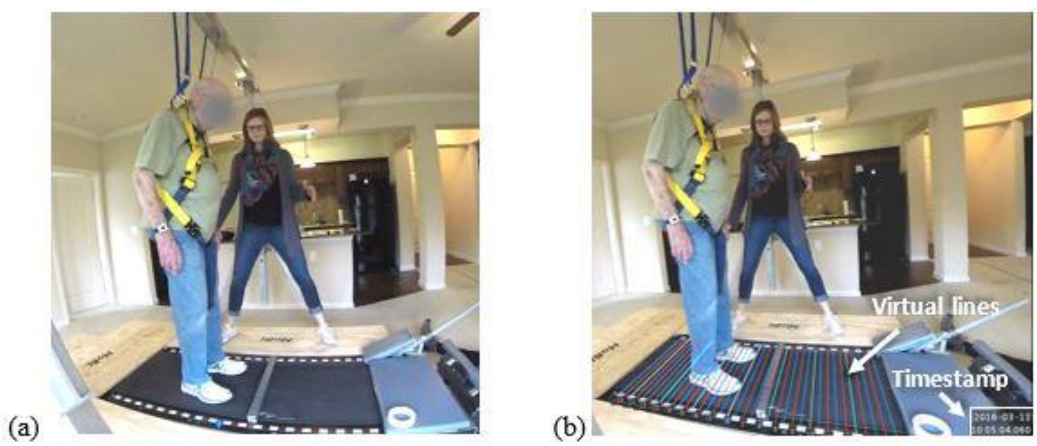


Figure 3. Depiction of sagittal plane video recording (a) before and (b) after MATLAB processing. Virtual lines were overlaid on the modified treadmill to calculate step length while the time stamp was used to calculate reaction time.

Once allocated into a group, BRT and TC training interventions were performed on-site three times per week for four weeks (total 12 sessions). Both groups performed approximately 30-minute training sessions (the time stipulated by the duration of the BRT session). Subjects in both groups were required to complete 75% (or 9 of 12 training sessions) to be considered compliant with training. After the four weeks of training, subjects performed the four remaining assessments one week, one month, three months, and six months after completing training.

Balance Recovery Training (BRT)

BRT sessions involved repeatedly exposing subjects to trip-like perturbations on a modified treadmill (Fig. 4) that required quick reactive stepping movements to successfully recover balance as in [11]. Each BRT session either consisted of 40 perturbations (with rest breaks every 10 trials to minimize fatigue) or as many that could be completed in the allotted 30 minutes. The number of trials was a compromise between maximizing the number of trials to improve motor learning [30] and limiting the number of trials to ensure that subjects could complete the trials without being physically exhausted. Additionally, the number of trials is comparable to other studies involving balance training in other populations [31, 32]. Varying the perturbation speeds (between 0.22 and 1.07m/s) in a random order made the training task itself more difficult, but promoted improved learning and adaptability to other tasks [33]. These aspects are important, because a sufficient challenge improves learning and success is necessary for training of lower extremity coordination [30].

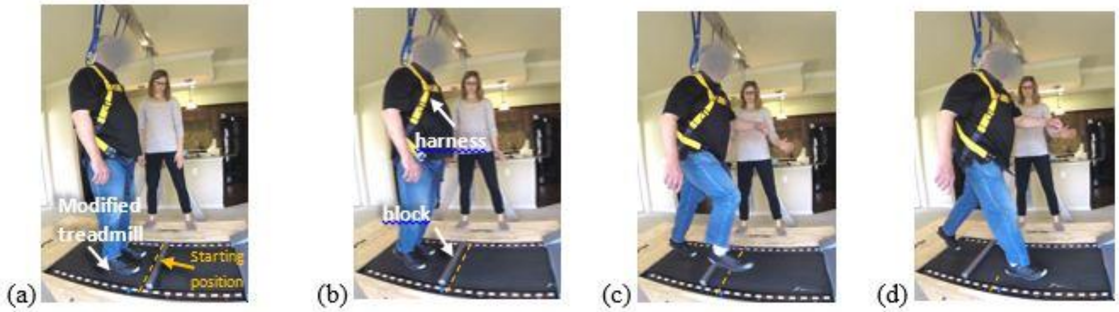


Figure 4. (a) Modified treadmill set-up used during assessments and BRT where subjects wore a harness and had spotters available for safety and comfort. Upon treadmill movement (b), the feet will be displaced posteriorly, and a forward fall will be induced (much like after a trip while walking). To recover balance, subjects must attempt to step over the block placed in front of them (c), as if stepping over a real-life obstacle (d).

Tai Chi (TC)

Tai Chi sessions (Fig. 5) consisted of twelve unique sequences selected from the Yang Short Form, which included three variations of unipedal stance.

Figure 5. Moves included in the Tai Chi sessions included (a) unipedal stances, (b) shifting weight, and (c) bending.

The twelve unique sequences were chosen based on their focus on balance (i.e. unipedal stance and weight shifting) as well overall mobility (i.e. bending). TC was presented at the identical frequency of the BRT, in order to control for intervention exposure. The sequence of moves practiced included:

1. *Parting the Wild Horse's Mane (3x)* practiced shifting weight from left to right
2. *Grasp the Sparrow's Tail (left)* practiced shifting weight forwards and backwards
3. *Grasp the Sparrow's Tail (right)* practiced shifting weight forwards and backwards
4. *Single Whip* practiced shifting weight to the right
5. *High Pat on the Horse* practiced unipedal stance
6. *Heel Kick (right)* practiced unipedal stance (Fig. 5a)
7. *Strike Tiger's Ears* practiced shifting weight forward
8. *Heel Kick (left)* practiced unipedal stance
9. *Snake Creeps through Grass, Rooster Stands on One Leg (left)* practiced unipedal stance
10. *Snake Creeps through Grass, Rooster Stands on One Leg (right)* practiced unipedal stance
11. *Fair Lady Works the Shuttles (right & left)* practiced shifting weight forward and to the side (Fig. 5b)
12. *Needle at the Sea Bottom* practiced bending down (Fig. 5c).
13. *Fan through the Back* practiced shifting weight to the left
14. *Turn, Deflect, Parry and Punch* shifting weight forward
15. *Cross Hands* practiced shifting weight from side to side

TC was led by a trainer with experience in leading community-based Tai Chi for older adults; thus, the two groups were led by different trainers. Although other studies investigating the impacts of Tai Chi have varied in duration and frequency (1x/week for

16 weeks [34] and 3x/week for 6 months [35]), intensive TC practice (5x/week for 3 weeks [36] and (2x/week for 12 weeks [20]), have also been successful in improving mobility measures, analogous to those presented here.

Falls

The number of falls that occurred during seven months of study (including the four-week training interventions) were also recorded. A fall, using standard definitions [37, 38], was defined as a person unintentionally coming to rest on the ground or lower level not caused by loss of consciousness, stroke, or overwhelming hazard. Falls were tracked by a member of the research team who called subjects on a bi-monthly basis to inquire about any falls or change in health (as per standard protocol (e.g. [39]). If a fall occurred, further information was recorded on the aspects of the fall to determine the number of reported trip-induced falls, because the specificity of BRT was expected to provide the most benefit for these falls.

Statistical Analysis

Multiple statistical analyses were performed. To compare subject characteristics between groups, a *t*-test was used to compare continuous variables, and a Fisher's Exact Test was use to compare nominal variables (i.e. gender). To compare baseline measurements between groups, a *t*-test was used. To evaluate Hypothesis 1, (*Compared to TC subjects, BRT subjects will show greater improvement and retention in balance recovery ability compared to their baseline measures*) change values were first calculated for each subject and for each dependent variable related to balance recovery ability by subtracting the baseline values from each post-training value. Differences in *improvement* between groups were evaluated using a *t*-test on changes from baseline to 1W post-training. Differences in *retention* were evaluated using a *t*-test on changes from baseline to all other post-training assessments (1M, 3M, and 6M). To evaluate Hypothesis 2, (*Compared to TC subjects, BRT subjects will show lesser improvement and retention in clinical measures of balance and mobility compared to their baseline measures*), the same analysis described for Hypothesis 1 was used, but with clinical balance/mobility measures. No correction for multiple comparisons were performed because all comparisons were planned, and due to the exploratory nature of this investigation. Individual *p*-values are reported to infer the statistical significance of the findings.

Project 2: Assess the feasibility of providing BRT in retirement communities, including issues related to older adult subject recruitment and compliance

All subjects who completed the BRT training were interviewed. Subjects were asked to complete a semi-structured interview focused on their perspectives on the intervention they participated in as well as potential adaptions that could be made to make the training more available to a wider range of adults [40]. Interview questions were divided into four main categories consisting of:

1. *Recruitment*

    1.1. What reasons do you think other people, like you, might not participant in the exercise program? [Prompt: Too busy? Lack of familiarity with the exercise?]

    1.2. Do you have any suggestions on how we might engage more people, like you, in the balance training (or Tai Chi) exercise program? Is there anything we can do differently? [Prompt: Any other incentives?]

2. *Compliance*

    2.1. Can you tell me what you liked and disliked about the balance recovery training (Tai Chi)? [Prompt: anything else you liked; anything else you did not like?]

3. *Efficacy*

    3.1. Do you think the exercise program helped your balance?

    3.2. Your confidence?

    3.3. Your independence?

    3.4. Why?

4. *Sustainability*

    4.1. Is there anything you would change about the exercise program to make it more effective or more enjoyable?

    4.2. If this program was continued as a weekly/biweekly/monthly exercise program, would you continue to participate? If so, what would your preference be for the frequency of the program (i.e. weekly, biweekly, monthly, etc.)

Subject interviews were audio recorded, transcribed, and then qualitatively analyzed using a deductive and inductive approach [41-43]. By using a semi-structured interview focused on the Consolidated Framework for Implementation Research [44], a deductive approach was used to analyze the data. However, an inductive approach was used by developing themes and sub-themes from meaning units. Meaning units were generated by identifying key phrases from each response given by a subject that would contribute either to understanding the perception of their respective intervention or how to better incorporate the intervention in order to maintain a balance program in the future.

To evaluate Hypothesis 3 (*Subjects at retirement communities will rate BRT positively, and provide important feedback on how BRT would best be implemented and sustained in these settings*) sub-themes from each meaning units were developed to identify broader themes within each of the nine questions. In order to identify whether subjects participating in BRT would rate it positively, themes from compliance question (question 3) as well as the efficacy questions (questions 4-7) were grouped to identify commonalities and to qualitatively assess BRT perceptions. In order to gather information on feedback and implementation of BRT, themes from the recruitment (question 1) and compliance question (question 3) were compared with themes from the recruitment (question 2) and sustainability questions to qualitatively assess future implementation and improvements of BRT.

RESULTS

Project 1

Subject age, gender, height, or mass did not differ between groups (Table 1).

Table 1. Subject characteristics (mean ± standard deviation)

	BRT		TC		***p* value**
Age (years)	81.33 ± 7.50		83.08 ± 4.83		0.471
Gender	male	female	male	female	
	5	10	5	7	
Height (m)	1.63 ± 0.11		1.64 ± 0.11		0.706
Mass (kg)	77.01 ± 15.23		83.42 ± 16.97		0.838

At baseline, minimal differences existed between groups (Table 2). Balance recovery measures exhibited one difference between groups in that reaction time at 2.4 mph was 0.03 sec shorter among BRT subjects compared to TC subjects ($p = 0.012$). Clinical measures of balance and mobility (Table 3) did not differ between groups.

Table 2. Baseline balance recovery measures (mean ± standard deviation),
** 0.05 > *p* > 0.01

	Speed	**BRT**	**TC**	***p* value**
Step length (m)	0.8 mph	0.40 ± 0.16	0.45 ± 0.10	0.602
	1.6 mph	0.52 ± 0.14	0.58 ± 0.11	0.418
	2.4 mph	0.65 ± 0.09	0.56 ± 0.20	0.181
Step Time (sec)	0.8 mph	0.25 ± 0.10	0.29 ± 0.07	0.370
	1.6 mph	0.22 ± 0.06	0.25 ± 0.06	0.319
	2.4 mph	0.22 ± 0.03	0.18 ± 0.06	0.103
A/P Speed (m/s)	0.8 mph	1.61 ± 0.26	1.55 ± 0.16	0.425
	1.6 mph	2.39 ± 0.39	2.33 ± 0.23	0.451
	2.4 mph	2.94 ± 0.43	3.12 ± 0.30	0.492
Reaction time (sec)	0.8 mph	0.38 ± 0.07	0.41 ± 0.09	0.419
	1.6 mph	0.34 ± 0.06	0.34 ± 0.06	0.906
	2.4 mph	0.30 ± 0.03	0.33 ± 0.03	0.012 **
Harness Support	0.8 mph	0.17 ± 0.31	0.29 ± 0.45	0.312
	1.6 mph	0.73 ± 0.84	0.75 ± 0.66	0.758
	2.4 mph	1.68 ± 0.60	1.83 ± 0.35	0.224

Table 3. Baseline clinical measures of balance and mobility (mean ± standard deviation)

	BRT	TC	*p* values
Time Up and Go (sec)	12.82 ± 4.68	14.44 ± 6.43	0.445
Max Unipedal Stance Time (sec)	5.46 ± 6.58	3.64 ± 3.15	0.330
Forward Max Step Length (m)	0.53 ± 0.14	0.48 ± 0.13	0.238
Berg Balance Test	47.41 ± 4.58	44.58 ± 5.42	0.131
Tinetti Balance Test	13.35 ± 1.37	12.50 ± 1.83	0.129
Tinetti Gait Test	10.24 ± 1.64	10.75 ± 1.42	0.467
ABC Scale (% confidence)	73.82 ± 13.82	76.04 ± 16.19	0.844

Changes in balance recovery measures at 1W indicated differences in improvement between BRT subjects and TC subjects (Figs. 6 and 7). Four measures indicated greater improvement among BRT subjects. Subjective rating of balance recovery ability increased by 47.3% among BRT subjects and decreased 4.5% among TC subjects ($p = 0.001$). Step length at 0.8mph increased by 0.12 m (30.2%) among BRT subjects and decreased by 0.03m (6.6%) among TC subjects ($p = 0.058$), while step length at 1.6mph increased by 0.14m (26.6%) among BRT subjects, and decreased by 0.01m (1.6%) among TC subjects ($p = 0.022$). Reaction time at 1.6mph decreased by 0.03 sec (7.6%) among BRT subjects and increased 0.02 sec (5.6%) among TC subjects (*p* = 0.030). One balance recovery measure indicated greater improvement among TC subjects than BRT subjects. Step time at 1.6mph increased by 0.05 sec (20.5%) among BRT subjects and decreased 0.01 sec (1.6%) among TC subjects (*p* = 0.073).

Changes in balance recovery measures at 1M, 3M, and 6M indicated differences in retention between BRT and TC subjects (Figs. 6 and 7). Four measures indicated greater retention among BRT subjects than TC subjects. Subjective rating of balance recovery ability increased more among BRT than TC at 1M (*p* = 0.017), 3M (*p* = 0.004), and 6M (*p* = 0.004). At 1M, step length at 1.6 mph increased by 0.12 m (22.6%) among BRT subjects and decreased 0.001m (0.2%) among TC subjects (*p* = 0.045). At 3M, step time at 2.4 mph decreased by 0.01sec (3.3%) among BRT subjects and increased by 0.05 sec (25%) among TC subjects (*p* = 0.093). At 3M, harness support at 1.6mph decreased by 0.35 (47.6%) among BRT subjects and decreased by 0.19 (25.9%) among TC subjects (p = 0.081). One measure indicated greater retention among TC subjects that BRT subjects. At 1M, reaction time at 0.8 mph increased 0.004sec (1.1%) among BRT subjects and decreased by 0.06 sec (15.6%) among TC subjects (*p* = 0.036).

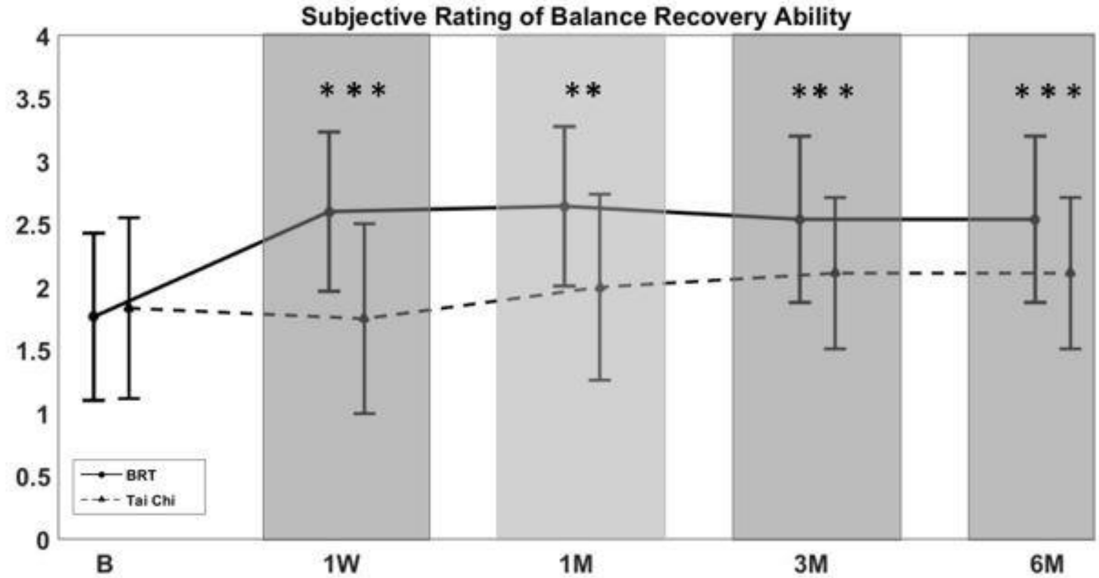


Figure 6. Subjective rating of balance recovery ability (mean ± standard deviation) at baseline (B), one week (1W), one month (1M), three months (3M), and six months (6M) after the end of training. Statistical differences notate differences between groups compared to baseline scores (* 0.1 > *p* > 0.05, ** 0.05 > *p* > 0.01, *** *p* < 0.01).

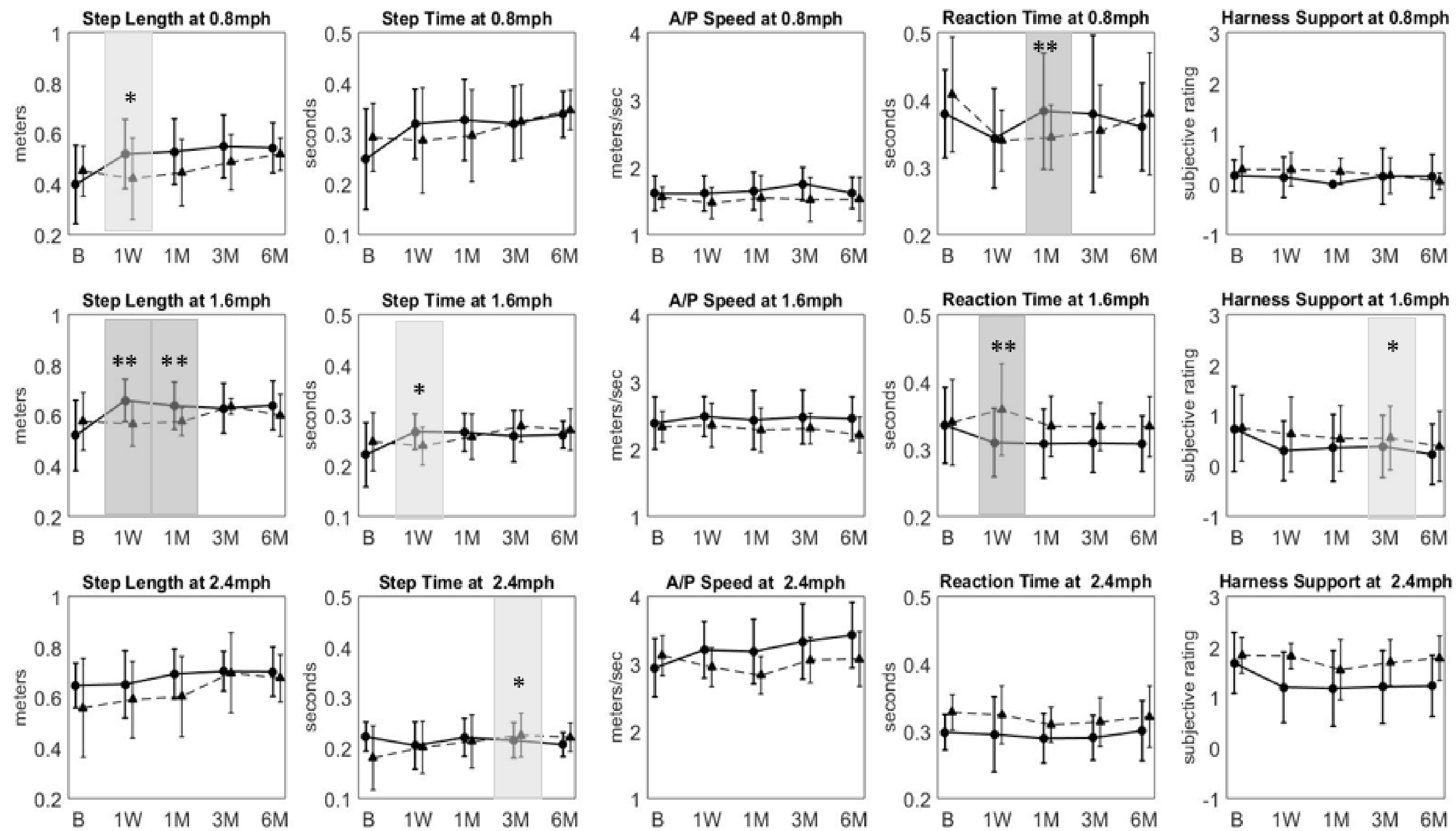
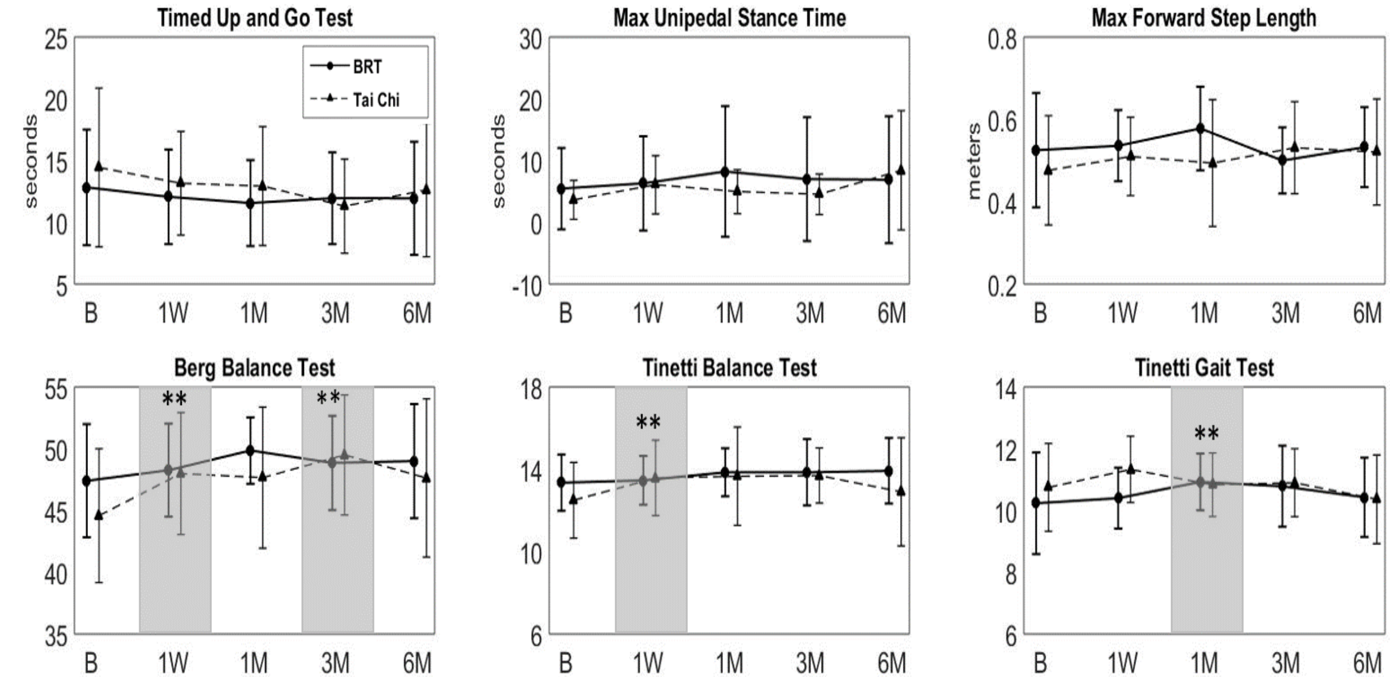


Figure 7. Balance recovery measures (mean ± standard deviation) at 0.8, 1.6, and 2.4mph recorded at baseline (B), one week (1W), one month (1M), three months (3M), and six months (6M) after the end of training. Statistical differences indicate differences between groups compared to baseline scores (* 0.1 > p > 0.05, ** 0.05 > p > 0.01, *** p < 0.01).



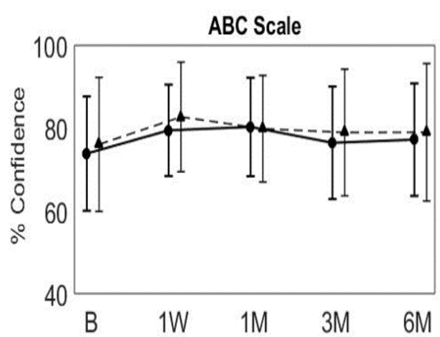


Figure 8. Clinical measures of balance and mobility (mean ± standard deviation) recorded at baseline (B), one week (1W), one month (1M), three months (3M), and six months (6M) after the end of training. Statistical differences indicate differences between groups compared to baseline scores (* $0.1 > p > 0.05$, ** $0.05 > p > 0.01$, *** $p < 0.01$).

Changes in two clinical measures of balance and mobility at 1W indicated greater improvement among TC subjects than BRT subjects (Fig. 8). At 1W, Berg Balance Test increased 3.42 points (7.7%) among TC subjects, and increased 0.85 points (1.8%) among BRT subjects ($p = 0.030$). At 1W, Tinetti Balance Test increased 1.08 points (8.7%) among TC subjects, and increased 0.11 points (0.85%) among BRT subjects ($p = 0.024$).

Changes in clinical measures of balance and mobility at 1M, 3M, and 6M indicated differences in retention between BRT and TC subjects (Fig. 8). One measure indicated greater retention among TC subjects. At 3M, Berg Balance Test increased 4.92 points (11.0%) among TC subjects, and increased 1.45 points (3.0%) among BRT subjects. One measure indicated greater retention among BRT subjects. At 1M, Tinetti Gait Test increased 0.69 points (6.8%) among BRT subjects, and increased 0.08 points (0.8%) among TC subjects. No changes in clinical measures of balance and mobility differed between groups at 6M.

Due to the nature of the older adult population used for this study, several subjects were unable to complete all post-training assessment measures (Appendix A1). Reasons for non-compliance include:

1. Following instructions from their doctor to either limit or eliminate physical activity due to a new or pre-existing health condition
2. Deciding by themselves to either limit or eliminate physical activity due to a new or pre-existing health condition
3. Caring for spouse with severe health complications

4. Travelling for an extended amount of time (more than three months)
5. Requesting to not participate in the treadmill portion of an assessment session either in part or full due to fear, anxiousness, or physical inability

Some data was also missing from the analyses. Reasons for missing data include:

1. Subject stepped on the block during a treadmill perturbation, therefore accurate data for step length, step time, or A/P speed could not be recorded
2. Subject did not attempt to step during a treadmill perturbation, therefore data for step length, step time, A/P speed, or reaction time could not be recorded
3. Investigator (JA) decided to not expose subject to 2.4mph perturbation if they were unable to successfully recover at 1.6mph after the second attempt

Falls

No subjects fell during the four weeks of training for either intervention. During the six month follow-up span, two BRT subjects and four TC subjects experienced trip-induced falls.

Project 2

Initial subject response to the interview questions assessing the perception and feasibility of a BRT resulted in 169 initial meaning units, which were further broken down into 70 themes (Table 4). Additionally, only themes that were recorded from at least two subject responses were used during analysis in order to identify commonalities among different subjects.

Table 4. Breakdown of initial meaning units and resulting themes

	Recruitment		**Compliance**		**Efficacy**			**Sustainability**		**Total points**
Initial number of meaning units	40	21	30	12	14	12	12	10	18	169
Number of themes	8	6	15	7	6	4	8	7	9	70
Number of multi-response themes	6	6	6	4	3	4	1	2	4	36

To assess the feasibility and efficacy of BRT as exercise program in retirement communities, subjects were asked if they noticed improvements in their balance, confidence, and independence and to identify key examples to support their answer. Of the subjects who answered the question, 10 out of 13 subjects reported improvements in their balance, nine out of 12 subjects reported improvements in their confidence, and six out of 13 subjects reported improvement in their independence. Answers provided to all three questions were assessed and combined, resulting in four common themes: improvement in balance recovery ability (proactively or reactively preventing a fall), improvement in daily activities (walking, moving around furniture, maneuvering steep terrain, etc.), increased body (i.e. foot placement, gait, posture etc.) and balance (i.e. reduced stumbling) awareness, and increased awareness of the environment (i.e.

identifying potential trip obstacles). Three of the four themes were found to support a subject's perceived improvement in balance, all four themes were reported as examples of perceived improvement in confidence, and one theme was mentioned to support perceived improvement in independence (Table 5).

Table 5. Themes generated from subject justifications for perceived improvements in balance, confidence, and independence after completing BRT. 'X's indicate the factors demonstrating BRT efficacy (listed along top) were supported by the indicated theme (listed along left-most column).

Theme	Balance	Confidence	Independence
Improvement in balance recovery ability		X	
Improvement in daily activities	X	X	
Increased balance/body awareness	X	X	
Increased awareness of the environment	X	X	X

To gather information on feedback and improvements to BRT, answers provided for the recruitment, compliance, and sustainability questions were compared to identify common themes. Seven suggestion-based themes were generated from answers provided by subjects on what they "liked about the program (compliance)" and "suggestions on how to engage more people (recruitment)". Similarly, seven BRT-deterring themes were generated from answers on what subjects "disliked about the program (compliance)" and "reasons why other might not participate in BRT (recruitment)". The BRT-deterring themes also provided vital information to assess the barriers to implementation and sustainability of a more permanent program. The suggestion-based themes about BRT were qualitatively assessed against the BRT-deterring themes to determine whether subject suggestions could be directly applied to mitigate subject concerns and whether any unresolved outliers were present (Table 6). All BRT-deterring themes were addressed by at least one suggestion-based theme. ‘Education on falls’ and ‘BRT health benefits’ addressed the most subject concerns. ‘Anxiety while on the treadmill’ benefitted from the most suggestion-based themes while ‘abrupt treadmill movements and high treadmill speeds’ only benefitted from the suggestion to ‘lower treadmill speeds’.

Table 6. Themes generated from subject responses representing subjects' positive experiences with BRT as well as suggestions to increase involvement, which were compared to subjects' experience with BRT and reasons why others might not participate. 'X's indicate subject suggestion-based themes (listed along top) could be utilized to mitigate BRT deterring-based themes conjured by subjects.

Suggestion-based themes

BRT-deterring themes	Education on falls	Education on health benefits	Peer testimony and demonstrations	Encouragement	Increased advertising	Lower treadmill speeds	Incorporate TV or other distractions
Anxiety on treadmill	x	x	x	x		x	x
Negative perceptions about BRT	x	x	x		x	x	x
Not interested	x	x	x		x		
Lack of encouragement	x	x	x	x			x
Not educated on the importance of fall prevention	x	x	x		x		
Competing exercises and activities	x	x					x
Abrupt treadmill movements and high treadmill speeds						x	

Project Timeline

The projects presented spanned over two years, dominated by quantitative (project 1) and qualitative (project 2) data collection as well as coursework (Table 7).

Table 7. Timeline of my Masters of Science degree research project and course requirements

	Fall 2015	Spring 2016	Summer 2016	Fall 2016	Spring 2017
Course Requirements					
Quantitative Data Collection					
Qualitative Data Collection					
Data Analysis					
Prepare Thesis Proposal					
Write Thesis					
Final Defense					
Publish results					
Thesis Submission					

DISCUSSION

The goals of this study were to evaluate the efficacy (Project 1) and feasibility (Project 2) of BRT as an on-site fall prevention intervention for older adults. Hypothesis 1 (*Compared to TC subjects, BRT subjects will show greater improvement and retention in balance recovery ability compared to their baseline measures)* addressed the efficacy of BRT compared to an intervention known to reduce falls. Hypothesis 1 was supported based on the greater improvements in subjective rating of balance recovery ability and balance recovery measures at 1W (improvement) among BRT than TC subjects, as well as greater improvements in balance recovery measures at 1M, 3M, and 6M (retention) among BRT subjects compared to TC subjects. Hypothesis 2 (*Compared to TC subjects, BRT subjects will show lesser improvement and retention in clinical measures of balance and mobility compared to their baseline measure)* addressed the scientific question as to whether the training principle of *specificity of training* can be leveraged to improve balance recovery among older adults residents of retirement communities.

Hypothesis 2 was supported based on the greater improvements in clinical measures at 1W (improvement) among TC than BRT subjects, as well as greater improvements in clinical measures at 1M and 3M (retention). Hypothesis 3 *(Subjects at retirement communities will rate BRT positively, and provide important feedback on how BRT would best be implemented and sustained in these setting)* addressed the feasibility of BRT as an on-site balance training intervention. Hypothesis 3 was supported based on the positive self-reflection on balance, confidence, independence, and willingness to continue the BRT (positive rating) as well as the feedback on how the program could attract and maintain more subjects (implementation and sustainability). Taken together, task-specific training resulted in improvements in balance recovery measures up to six months after training. These results support the use of training specificity, and the use of on-site BRT for fall prevention among older adult residents of retirement communities.

Three general limitations associated with the study could have influenced our results. First, the optimal training schedule (number of sessions, frequency of sessions, and number of perturbations within each session) is unknown. Although several perturbation-based balance training studies have demonstrated positive results from a variety of training schedules (one day with five [15] and 20 [11] perturbations, two weeks with four, one hour sessions [5], and 6 months of sessions [19]), no study has attempted to optimize the number of sessions, the frequency of sessions, or the number of perturbations within a session. Longer and/or more frequent sessions could expose subjects to the neuromuscular responses needed to recover from a trip more often, but may be undesirable in terms of the larger commitment of time and effort required from participants, or their endurance. Even within each training session, the optimal manner with which to vary perturbation intensity is unknown. While motor learning is dependent on practicing a task that is complex enough to increase cognitive processing [5], the level of complexity required in order to structurally and functionally change the nervous system is unknown [6]. For example, perturbation speeds could gradually increase as the subject improves, speeds be varied randomly, or a combination of both approaches could be adopted.

The second general limitation of this study was that the variability in subject mobility, physical capability, and physical activity level may have contributed to variability in responses to training, and the subject's capacity to improve from training. For example, some subjects used mobility aids sporadically throughout the day, while others did not. Some subjects regularly exercised outside of the training for this project, while for some, this project was their only exercise. This could have directly influenced a subject's fatigue level and physical health overtime (i.e. after the training portion of the study was complete). It is possible that some subjects may have benefitted from additional training, whereas other higher functioning subjects may experience a ceiling effect such that additional training would not provide and therapeutic benefit. Subject variability was also present within fear of falling on or off the treadmill, which could have affected their stepping responses (i.e. shorter steps), willingness to attempt clinical balance measurements (i.e. unipedal stance), or perception of the BRT (project 2). Some subjects frequently reported anxiety associated with their fear of falling on or off the treadmill, while other did not.

The third general limitation of this study was the limited accuracy of the technology used to quantitatively assess balance recovery ability given that testing was performed on-site at retirement communities rather than in a research lab. Overlaying digital lines over the sagittal plane video recordings allowed for quantifying stepping characteristics, but lacked the precision of the equipment available in a research lab. This may have increased the variability in some of our measures, and made it more difficult to identify differences between groups.

The subjective rating of balance recovery ability provided the most conclusive results with respect to differences in improvement and retention between groups. This rating may be viewed less favorably than the other quantitative, objective balance recovery measures given its subjective nature, but does have its advantages. In particular, it incorporates several aspects of balance recovery, and as a result, may provide a more sensitive measure for detecting subtle changes. The rating included (1) whether or not spotter support was used, (2) whether or not the subject successfully stepped over the block, and (3) an assessment of the amount of harness support provided (Appendix A1). Aside from harness support, the other balance recovery measures (step length, step time, A/P speed, and reaction time) would not have captured a subject's improvement in support level (spotter) or overcoming a tripping obstacle (block), which are both important when recovering from a trip in everyday activities. Furthermore, the subjective rating would account for all the values where data could not be collected (Appendix A2) because a subject either did not attempt a perturbation speed, did not attempt to step, or stepped on the block.

Balance recovery measures demonstrated more improvement and retention among BRT subjects than TC subjects. The improvements in subjective rating of balance recovery ability, reaction time (1.6mph), and step length (1.6mph) provided support for the principle of specificity of training among BRT subjects. Improvements in subjective rating of balance recovery ability highlight subjects' improvement in keys tasks associated with recovering balance, as mentioned above. Reaction time improvement parallel the quick, reactive nature of BRT, and step length improvement could indicate a subject's ability to successfully overcome the block. Significance of reaction time and step length improvements are also supported by other studies [8, 12, 17]. Greater retention in balance recovery measures among BRT subjects than TC subjects was supported by improvements in subjective rating of balance recovery ability at 1M, 3M, and 6M as well as 3M improvement in step time (2.4mph) and harness support (1.6mph). Interestingly, speed of administered perturbations appeared to have an impact on differences between groups. Most of the differences among both groups were exhibited at 1.6mph, which could suggest that 0.8mph might not be challenging enough to discriminate between groups and similarly, 2.4mph might be too difficult. For example, the 3M step time difference at 2.4mph and the TC subjects compared to BRT subjects could stem from the fact that eight out of the 27 subjects were excluded from analysis (Appendix A2). 2.4mph proved to be difficult for many of the subjects, and therefore accurate data for step time was difficult to obtain. Therefore, a difference might not have been detected if all subject values had been included because a more complete representation of the sampled population would have been reported. TC subject improvement in step time (1.6mph) and retention at 1M in reaction time (0.8mph) could be supported by variability between subjects and/or difficulty of discerning differences between groups at lower speeds.

Clinical balance measures improved more after training the slow, volitional movements during TC compared to the quick reactive movements during BRT. This similarity between the movements during TC and these clinical measures provide further support for the principle of specificity of training among older retirement community residents. The two clinical measures that improved more after TC were the Berg Balance test, consisting of 14 individual tests that examine balance, and the Tinetti Balance tests, consisting of nine individual balance tests. The other clinical measures of balance and mobility that did not show greater improvement among TC subjects depend upon speed (Timed Up and Go Test), a single balance test (Max Unipedal Stance Time), gait control (Tinetti Gait Test), and self-perception of balance (ABC scale) that might not be as similar to TC as the Berg and Tinetti Balance tests. Retention in improvements observed among TC subjects in the Berg Balance Test at 3M provide evidence for subjects to retain these improvements for an extended period. One study [45], evaluated the validity of the Berg Balance test among older residents who were dependent in activities of daily living, and found that a change of eight points on the test was required to demonstrate an impactful change in function. While the subjects in this study were *independent* in activities of daily living, the greater improvement among TC subjects (3.42 points) might not have translated to a functional change. Greater retention at 3M in the Tinetti Gait test among BRT subjects was difficult to explain given the lack of differences between groups at 1W, but may have resulted from learning effects among the BRT group when performing this test, or subtle improvements in walking due to the walking on the treadmill during BRT.

Implementation of BRT in retirement communities is supported by positive ratings among BRT subjects during semi-structured interviews. BRT subjects' perceived improvements in their balance and confidence suggests BRT has the potential to serve as an on-site exercise program aimed at reducing falls. Furthermore, perceived improvements in balance and confidence among BRT subjects were supported by subject reported improvements in daily activities as well as balance, body, and environment awareness, which suggest an increase in quality of life. Improvement in balance recovery ability (outside an experimental setting) was likely not suggested among BRT subjects as a justification for perceived improvement in balance since many did not experience a fall during the duration of the program. Instead, balance recovery ability served as a justification for perceived improvement in confidence, suggesting that BRT subjects felt more confident in their ability to successfully recover from a trip if they were exposed to one in their day-to-day lives. Compared to balance and confidence, only a few subjects reported differences in their independence after BRT. This may be a result of subjects already being independent residents of retirement communities, leaving less “room for improvement” compared to a less independent, older population.

BRT subjects also provided important constructive feedback on both the implementation and sustainability of BRT. In particular, BRT subjects noted issues related to older subject recruitment and compliance along with critical improvements. Per the suggestions developed by BRT subjects, many of the qualms and reasons why other residents of retirement communities might not participate could be mitigated, reinforcing the successful implementation of BRT. Of the suggestions generated by BRT subjects, education on falls as well as the health benefits of BRT appeared to address the most concerns among BRT subjects. While education alone been shown to not improve balance recovery when compared to balance-specific exercise programs, such as BRT [14], increased education could serve as addendum to BRT, thus engaging more residents and supporting the sustainability of BRT. Furthermore, of all the concerns generated by BRT subjects, the uneasiness due to the abrupt movements and high speeds of the treadmill was the only concern that was only addressed by one of the seven suggestions reported by BRT subjects. Although the abrupt treadmill movements at high speeds were constrained by assessment protocols, BRT as a recreational exercise could be individualized to consist of smaller, slower perturbations. However, it is unknown whether subjects would benefit from slower treadmill perturbations, as motor learning is dependent on the complexity of a task [6].

CONCLUSION

In conclusion, the efficacy of BRT was supported by greater improvement and retention in multiple measures of balance recovery among BRT subjects than TC subjects. Additionally, the training principle of specificity was apparent in that BRT elicited greater improvement in balance recovery measures, while TC elicited greater improvement in clinical measures of balance and mobility. The feasibility of BRT was supported by the positive rating of BRT and perceived improvement in balance, confidence, and independence among BRT subjects.

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APPENDIX

A1. Rubric for subjective rating of balance recovery ability

	Grabs spotter? -2 = yes 0 = no	**Steps over block?** 0 = unsuccessful 1 = takes multiple recovery steps or uses wrong foot 2 = yes	**Recovers balance?** 0 = no attempt to recover balance 1 = attempt, significant harness support 2 = attempt, minor harness support 3 = successfully recover	**Total Points**
0.8mph, first attempt				
0.8mph, second attempt				
1.6mph, first attempt				
1.6mph, second attempt				
2.4mph, first attempt				
2.4mph, second attempt				
TOTAL POINTS				

A2. Breakdown of the number of subjects who were excluded from analysis for each dependent variables. A row was highlighted if five or more subjects were excluded from analysis

	Assessment	**BRT**	**TC**	**Total**
Time up and go test	B	0	0	0
	1W	0	0	0
	1M	1	0	1
	3M	1	2	3
	6M	1	1	2
Maximum unipedal stance time	B	0	0	0
	1W	0	0	0
	1M	1	0	1

	3M	1	2	3
	6M	1	1	2
Max forward step length	B	0	0	0
	1W	0	0	0
	1M	1	0	1
	3M	1	2	3
	6M	1	1	2
Berg Balance Test	B	0	0	0
	1W	0	0	0
	1M	1	0	1
	3M	1	2	3
	6M	1	1	2
Tinetti Balance Test	B	0	0	0
	1W	0	0	0
	1M	1	0	1
	3M	1	2	3
	6M	1	1	2
Tinetti Gait Test	B	0	0	0
	1W	0	0	0
	1M	1	0	1
	3M	1	2	3

	6M	1	1	2
ABC Scale	B	0	0	0
	1W	0	0	0
	1M	1	0	1
	3M	1	2	3
	6M	1	1	2
Subjective Rating of Balance Recovery Ability	B	0	0	0
	1W	0	0	0
	1M	1	0	1
	3M	2	3	5
	6M	2	3	5
Step Length at 0.8mph	B	1	2	3
	1W	0	1	1
	1M	1	0	1
	3M	2	3	5
	6M	2	3	5
Step Time at 0.8mph	B	1	2	3
	1W	0	1	1
	1M	1	0	1
	3M	2	3	5
	6M	2	3	5

Anterior/Posterior Speed at 0.8mph	B	1	2	3
	1W	0	1	1
	1M	1	0	1
	3M	2	3	5
	6M	2	3	5
Reaction Times at 0.8mph	B	1	2	3
	1W	0	0	0
	1M	1	0	1
	3M	2	3	5
	6M	2	3	5
Harness Support at 0.8mph	B	1	2	3
	1W	0	0	0
	1M	1	0	1
	3M	2	3	5
	6M	2	3	5
Step Length at 1.6mph	B	1	2	3
	1W	1	0	1
	1M	1	1	2
	3M	2	3	5
	6M	2	3	5
Step Time at 1.6mph	B	0	0	0

	1W	1	0	1
	1M	1	1	2
	3M	2	3	5
	6M	2	3	5
Anterior/Posterior Speed at 1.6mph	B	0	0	0
	1W	1	0	1
	1M	1	1	2
	3M	2	3	5
	6M	2	3	5
Reaction Times at 1.6mph	B	0	0	0
	1W	0	0	0
	1M	1	1	2
	3M	2	3	5
	6M	2	3	5
Harness Support at 1.6mph	B	0	0	0
	1W	0	0	0
	1M	1	1	2
	3M	2	3	5
	6M	2	3	5
Step Length at 2.4mph	B	4	4	8
	1W	0	2	2

	1M	1	2	3
	3M	4	4	8
	6M	4	4	8
Step Time at 2.4mph	B	4	4	8
	1W	0	2	2
	1M	1	2	3
	3M	4	4	8
	6M	4	4	8
Anterior/Posterior Speed at 2.4mph	B	4	4	8
	1W	0	2	2
	1M	1	2	3
	3M	4	4	8
	6M	4	4	8
Reaction Times at 2.4mph	B	4	3	7
	1W	0	2	2
	1M	1	2	3
	3M	4	4	8
	6M	4	3	7
Harness Support at 2.4mph	B	4	3	7
	1W	0	2	2
	1M	1	2	3

	3M	3	4	7
	6M	4	3	7